(12) UK Patent Application (19) GB (11) 2 378 614 (13) A

(43) Date of A Publication 12.02.2003

(21) Application No 0119354.9

(22) Date of Filing 08.08.2001

(71) Applicant(s)
Samsung Electronics Company Limited
(Incorporated in the Republic of Korea)
416 Maetan-dong, Paldal-ku, Suwon,
Kyunggi-do, Republic of Korea

(72) Inventor(s)
Byron Bakaimis

(74) Agent and/or Address for Service
R.G.C.Jenkins & Co
26 Caxton Street, LONDON, SW1H 0RJ,
United Kingdom

(51) INT CL⁷
H04Q 7/38 , G01S 1/02 5/02

(52) UK CL (Edition V)
H4L LRPLX L213 L221
H4D DPBC DPDA D267 D34X D340 D341 D342 D549
D550 D560 D561 D576 D580

(56) Documents Cited
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US 6121927 A
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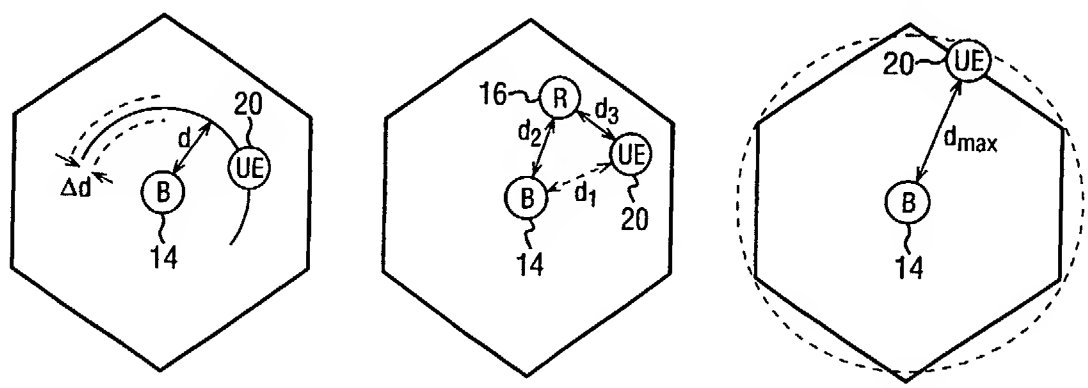
(58) Field of Search
UK CL (Edition T) H4D, H4L LRPLS
INT CL⁷ G01S, H04Q 7/38
Other: ONLINE: WPI, EPODOC, JAPIO, INSPEC

(54) Abstract Title
Mobile location using timing information for repeated signals

(57) A method of distinguishing, based on timing information, between a first path and a second path of a signal being transmitted between a node of a cellular network and a mobile terminal in a cell of said network, wherein said first path is a direct path between said node and said mobile terminal; and said second path is an indirect path between said node and said mobile terminal via an intermediate node of said cellular network.

FIG. 2(a) FIG. 2(b) FIG. 2(c)



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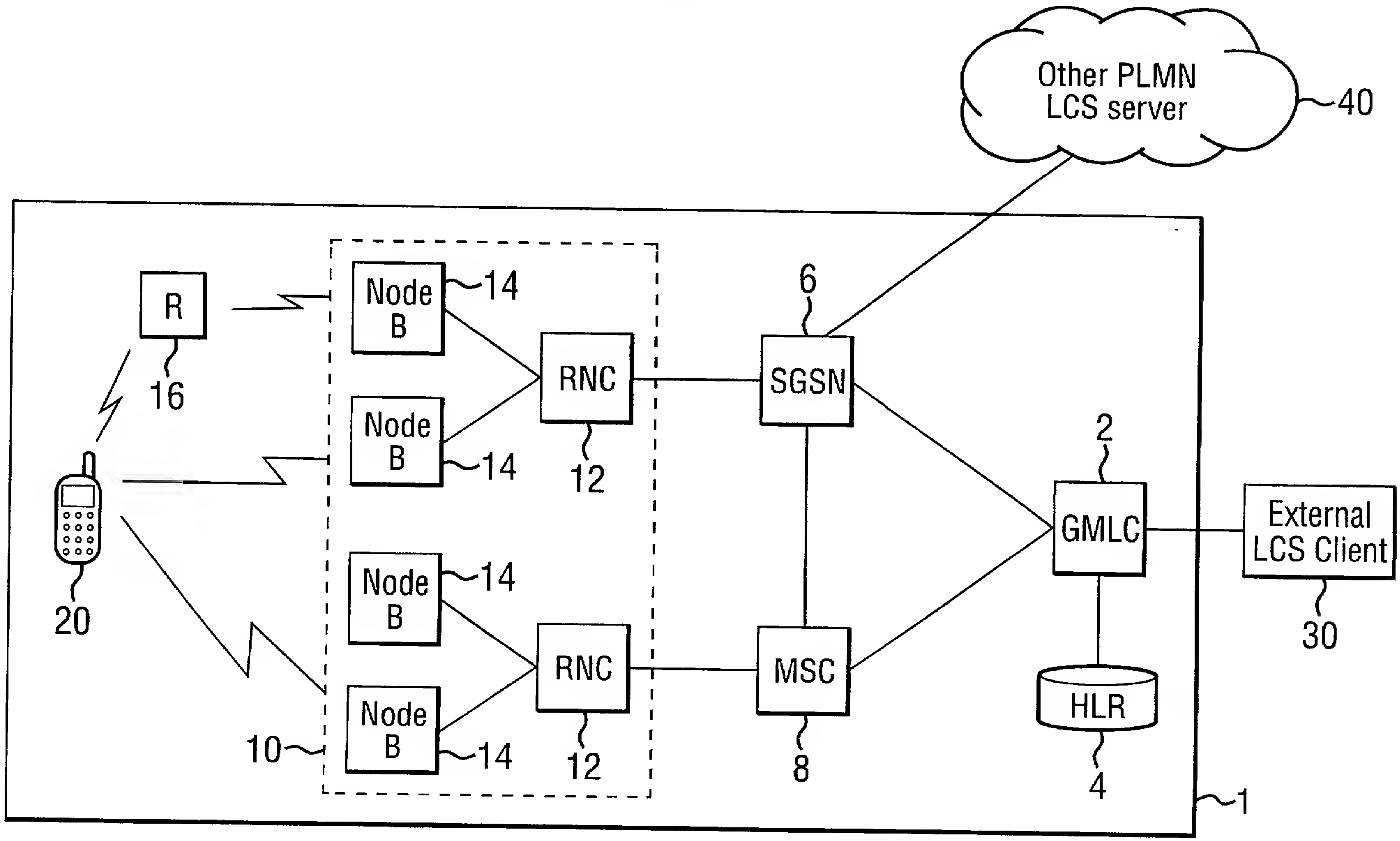
At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print incorporates corrections made under Section 117(1) of the Patents Act 1977.

FIG. 1



Other PLMN
LCS server
40
R
16
Node
B
14
RNC
12
SGSN
6
MSC
8
GMLC
2
HLR
4
External
LCS Client
30
20
10
1

FIG. 2(a)

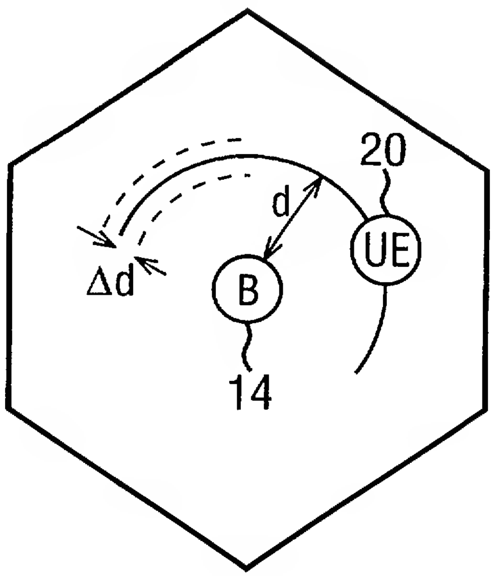


FIG. 2(b)

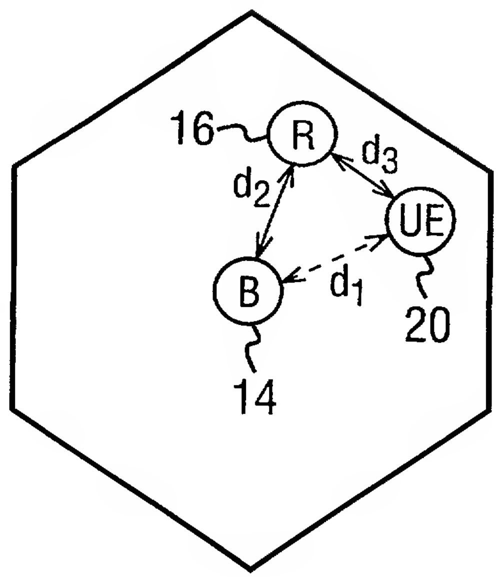


FIG. 2(c)

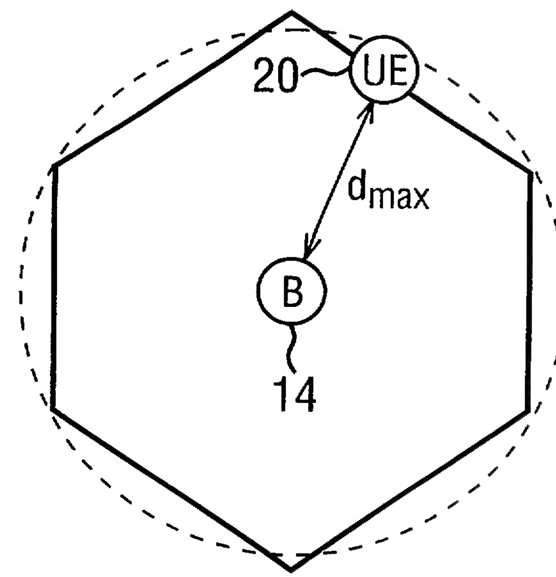


FIG. 3

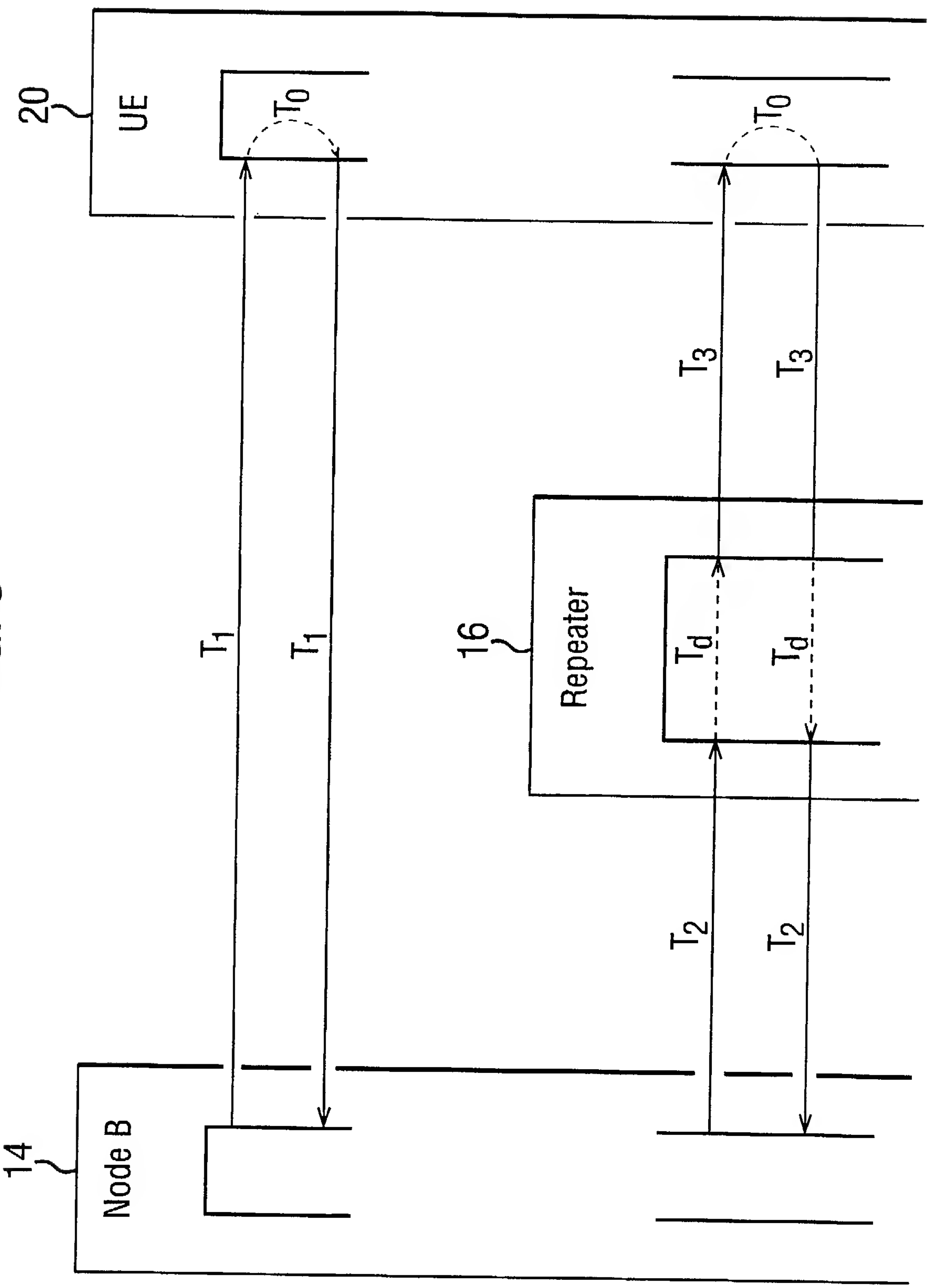


FIG. 4

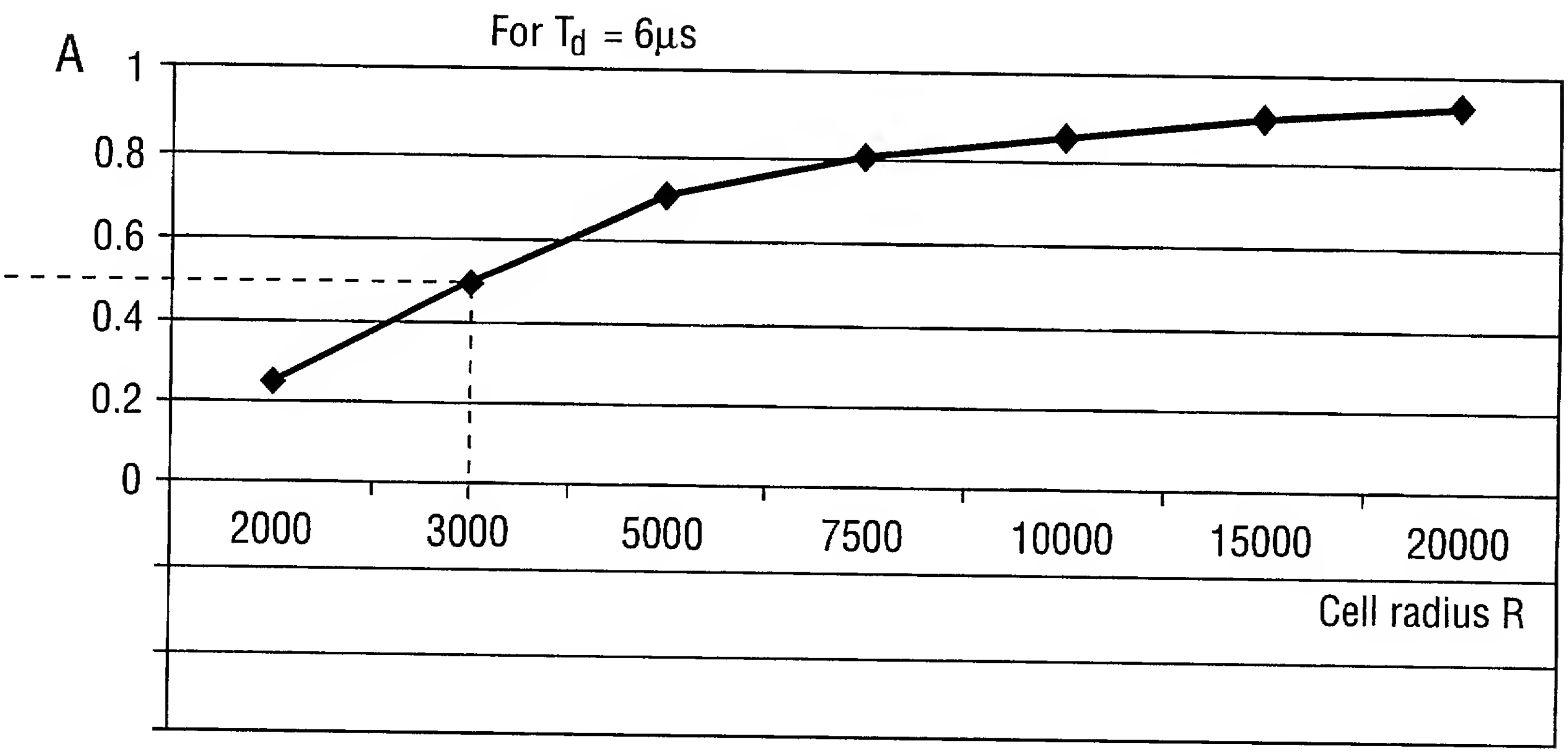

For T_d = 6μs
A
1
0.8
0.6
0.4
0.2
0
2000
3000
5000
7500
10000
15000
20000
Cell radius R

FIG. 5

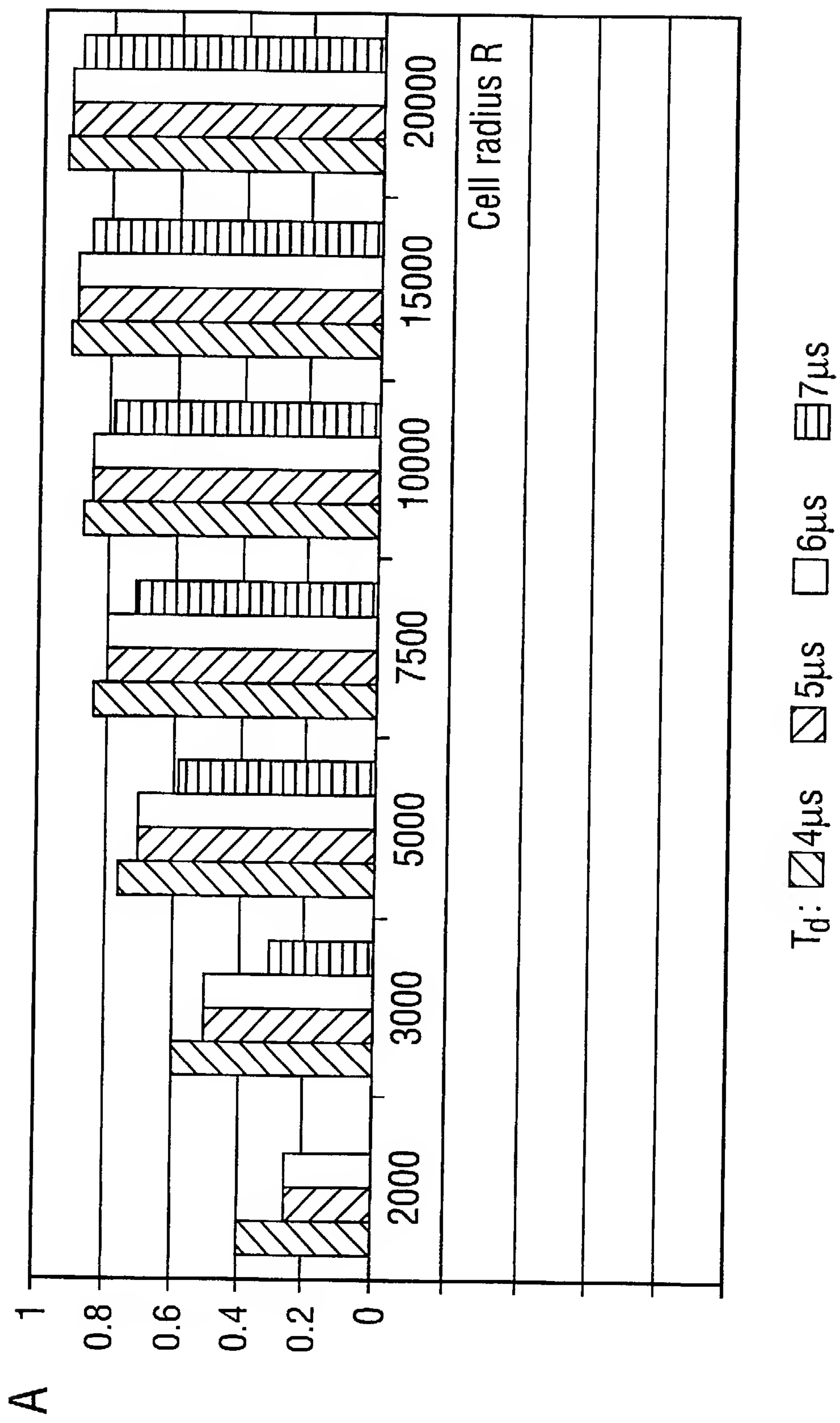
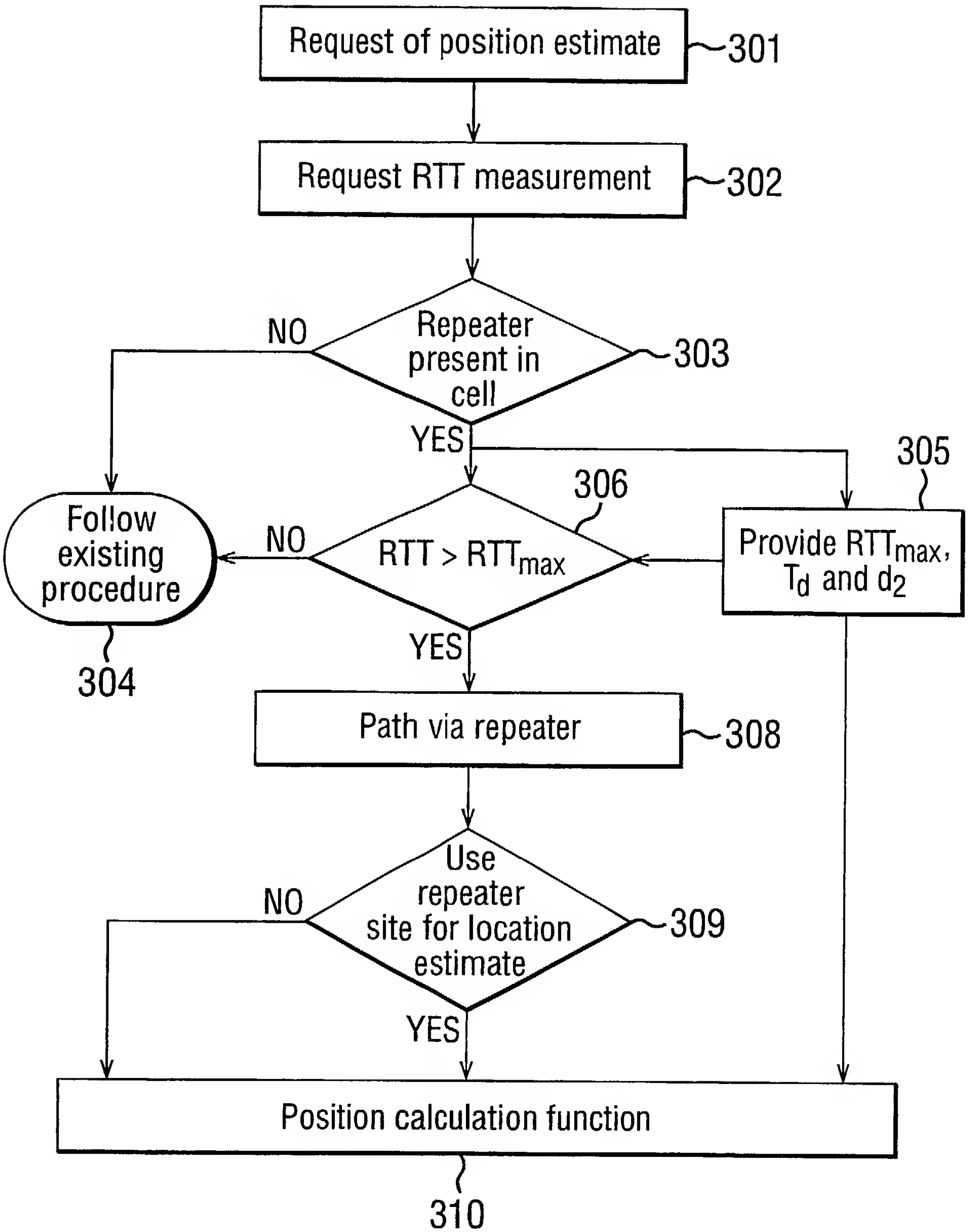
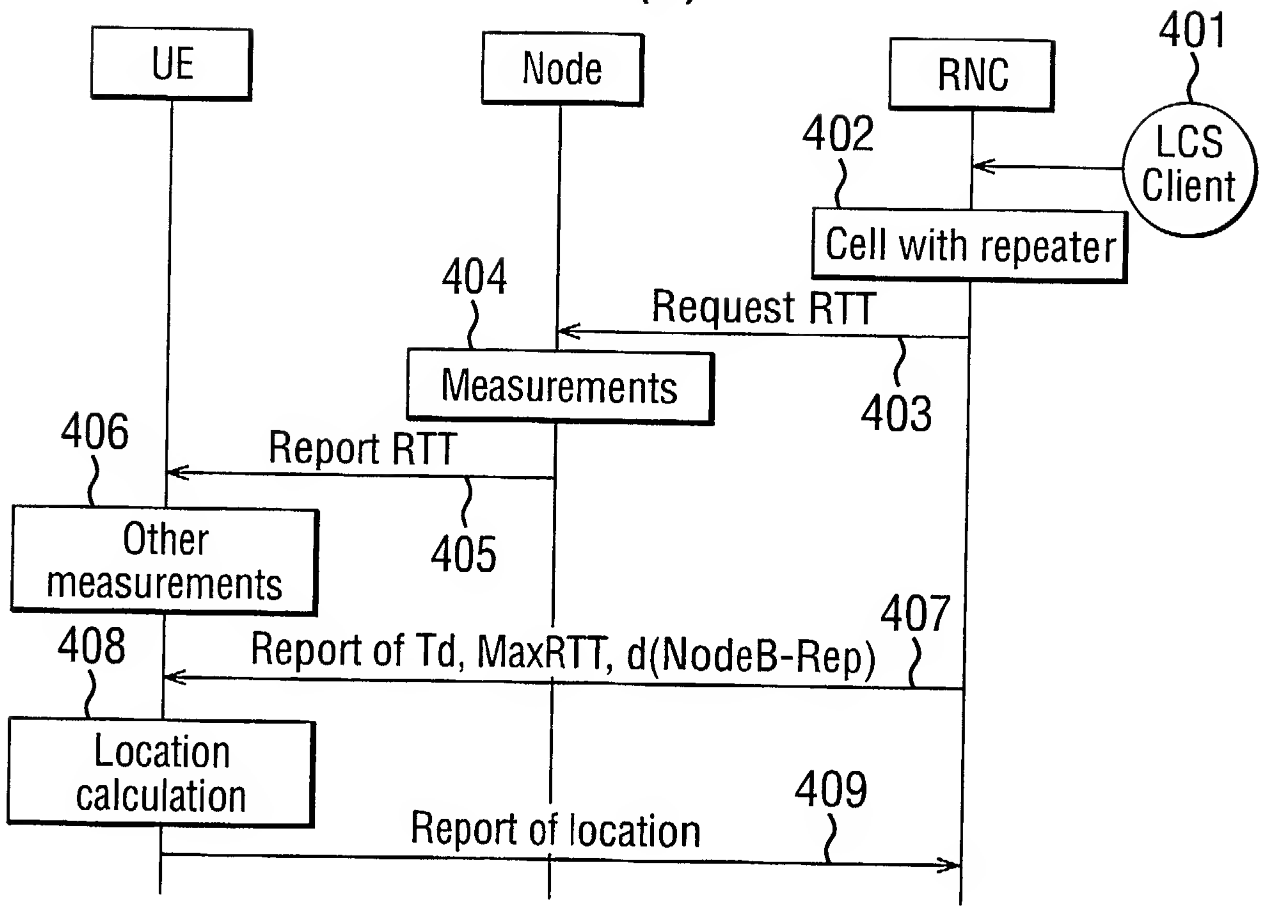

A
1
0.8
0.6
0.4
0.2
0
2000
3000
5000
7500
10000
15000
20000
Cell radius R
Td : 4μs 5μs 6μs 7μs

FIG. 6



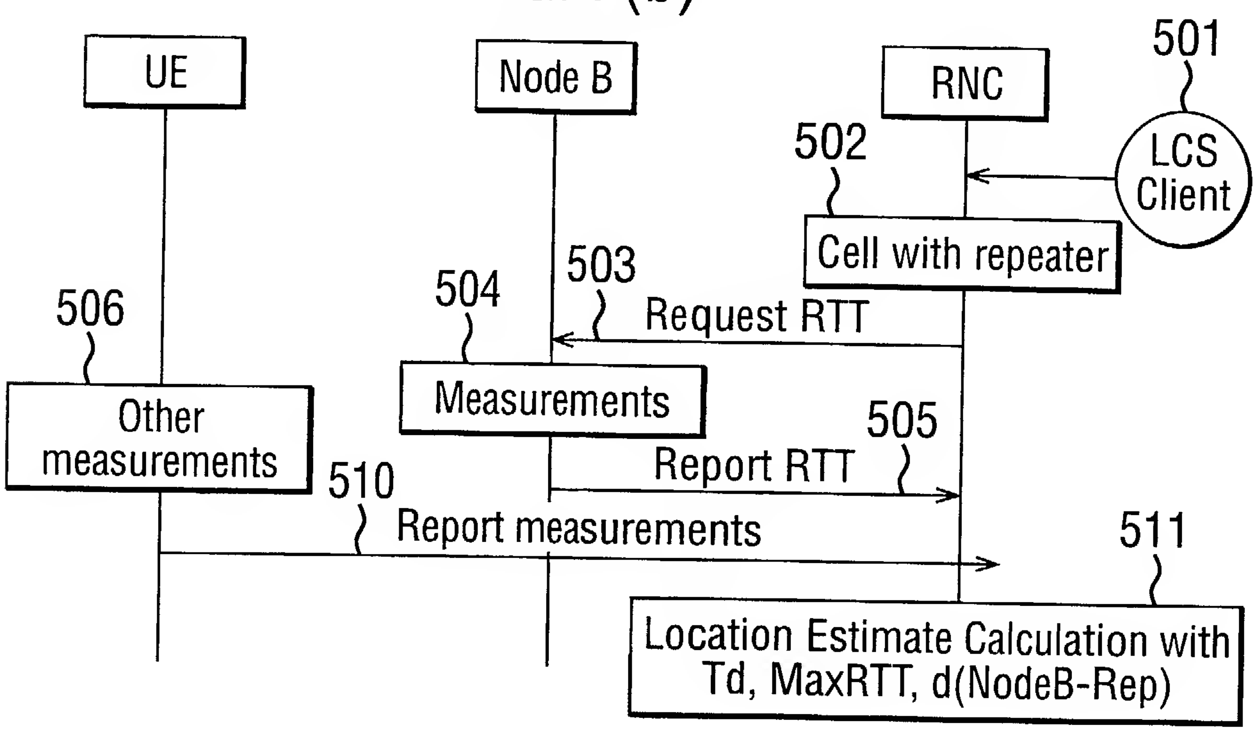
Request of position estimate
301
Request RTT measurement
302
Repeater present in cell
303
NO
YES
Follow existing procedure
304
305
Provide RTT_{max}, T_d and d_2
306
NO
RTT > RTT_{max}
YES
Path via repeater
308
Use repeater site for location estimate
309
NO
YES
Position calculation function
310

FIG. 7(a)



UE
Node
RNC
401
LCS Client
402
Cell with repeater
404
Request RTT
Measurements
403
406
Report RTT
Other measurements
405
407
408
Report of Td, MaxRTT, d(NodeB-Rep)
Location calculation
409
Report of location

FIG. 7(b)



UE
Node B
RNC
501
LCS Client
502
Cell with repeater
503
504
Request RTT
506
Other measurements
Measurements
505
Report RTT
510
Report measurements
511
Location Estimate Calculation with Td, MaxRTT, d(NodeB-Rep)

Method of Locating a Mobile Terminal

The present invention generally relates to cellular telecommunications and particularly to locating mobile units in such cellular telecommunications systems.

Cellular telecommunications networks are capable of determining the geographic location of a user equipment by making use of radio signals. The location information may either be requested by an external client or client application or may be utilised internally by the network. In cellular networks like for example the GSM or UMTS system, there are various possibilities to determine location information, as for example the determination of the nearest base station or more sophisticated methods like measurements of round trip times (RTT) or OTDOA (observed time difference of arrival). The idea behind the time based measurements like RTT or OTDOA measurements is to determine the transmission time T of a radio signal between a network node and the mobile station. By using the known transmission velocity of the signal (ie the velocity of light c), the distance d between the node and the mobile terminal can be derived according to the relationship $d = T \cdot c$. Details of location services (LCS) for GSM networks may be found in the GSM specifications GSM 02.71 (digital cellular telecommunications system (Phase 2+) – Location Services (LCS); service description; Stage 1) and GSM 03.71 (Digital cellular telecommunications system (Phase 2+) – Location Services (LCS); Functional description; Stage 2) and for the third generation UMTS

telecommunications networks in the Technical Specifications of the Third Generation Partnership Project 3G TS 23.171 (Technical Specification Group Services and System Aspects – Functional description of Location Services) and 3G TS 25.305 (Technical Specification Group Radio Access Network – Functional description of Location Services).

The uncertainty of the position measurement is network implementation dependent at the choice of the network operator. The uncertainty may vary between networks as well as from one area within a network to another. The uncertainty may be hundreds of metres in some areas and only a few metres in others. The uncertainty may also depend on the capabilities of the mobile station.

However, the accuracy of these time based measurement methods like RTT and OTDOA are substantially decreased if intermediate nodes like RF repeaters are present in a particular cell. In such a case a signal from a base station is received by a repeater, is then amplified and further transmitted by the repeater and is received by the mobile station. Thus the signal is transmitted over a distance which is greater than the direct path between the base station and the repeater, or the base station and the mobile station. In addition, the repeater introduces an internal time delay which further decreases the accuracy of the distance determination.

OTDOA as well as RTT measurements are meaningful only if they can be associated with the reference points – eg a base station or a repeater –

and if it can be known whether the signal path was direct or via an intermediate node like a repeater.

Although both the RTT and OTDOA measurements might be available in certain network implementations in order to determine the signal path, for other implementations only the RTT measurement may be used to deduct which reference point it was taken from. Thus, it would be advantageous to determine the signal path also in cases where only one type of time based measurement is available.

It is thus an object of the present invention to overcome the disadvantages described above and allow for a position determination in a network which includes repeaters with about the same accuracy as provided in a network that does not include repeaters. It is another object of the present invention to provide a reference point for time based positioning methods on which the calculation can thus be based.

It is another object of the present invention to identify the path of a radio signal, which is transmitted in order to determine the location of a mobile station in a cellular telecommunication network, as being direct or indirect via an intermediate node. Preferably, only one time based measurement, like for example a RTT measurement, is needed in order to determine the original path.

According to one aspect of the present invention there is provided a method of distinguishing between a first path and a second path of a signal being transmitted between a node of a cellular network and a mobile terminal

in a cell of said network based on timing information, wherein said first path is a direct path between said node and said mobile terminal; and said second path is an indirect path between said node and said mobile terminal via an intermediate node of said cellular network.

The path information may then be used in order to estimate location information of a mobile terminal. In this way the accuracy of location estimates for cells including intermediate nodes can be significantly enhanced.

Preferably, the path information is determined using only one time measurement related to the transmission time of a signal between said mobile terminal and said node to determine path information.

In this way the method can also be employed in implementation where only one time measurement, as for example a RTT measurement, is available.

Preferably, all the timing information used in the method is based on signals transmitted within said cell.

In this way a relatively simple method of identifying path information is provided, wherein the additional calculations are few and very simple.

According to another aspect of the present invention, there is provided a method of determining position information of a mobile terminal in a cell of a cellular telecommunications network, comprising the steps of: determining whether an intermediate node is present in said cell; determining path information of a signal transmitted between a base station node and said

mobile terminal if said intermediate node is present in said cell; and calculating said position information.

Preferably, the intermediate node is used as a reference point to calculate said position information.

For example, instead of using the base station as a point for location the intermediate node can be used. In this way the achieved results may even have a greater accuracy than the results achieved with the normal procedure, because the user equipment is usually closer to the repeater than to the serving base station. Furthermore both reference points, i.e. the base station and the repeater, could be used for the position estimated and potentially the accuracy can further be improved.

According to another aspect of the present invention, there is provided a computer program in a cellular telecommunications network capable of determining, based on timing information, whether a signal was transmitted between a mobile terminal and a node within a cell of said cellular network via an intermediate node, and wherein said timing information comprises: a time measurement t related to the transmission time of a signal between said mobile terminal and said node; and a reference value for a time delay T_d introduced by said intermediate node.

Preferably, the computer program is implemented in a positioning calculation function, which may be implemented either in the mobile terminal or in a node of the cellular network. In this way the path information and accordingly the location information can be determined by a positioning

calculation function, which may either be implemented in a node of the network so as for example the radio network controller (RNC) of a UMTS network or in the mobile terminal itself.

Preferably, the positioning calculation function is adapted to receive said time measurements and said reference values via signalling within said cellular network.

In this way, the additional signalling load as introduced by the present invention is very limited and does not add substantial additional complexity.

According to another aspect of the present invention, there is provided a method of designing a cellular telecommunications network, said network comprising a plurality of cells, at least one cell including a base station and a repeater for receiving, amplifying and transmitting signals to and from said base station, wherein said repeater is placed within said cell such that the cell radius R fulfils the condition:

$$R < T_d \cdot c / (1 - A),$$

wherein T_d is a time delay introduced by said repeater when a signal is transmitted between said node and a mobile terminal within said cell via said repeater and c is the velocity for transmitting said signal, and A is the ratio of the distance d_2 and the cell radius R, whereby d_2 is the distance between said base station node and said repeater.

In this way a cellular network is created wherein cells including a repeater have a maximal cell radius to ensure that location calculation may be carried out with a reasonable accuracy.

According to another aspect of the present invention there is provided a method of designing a cellular telecommunications network, said network comprising a plurality of cells, at least one cell including a base station and a repeater for receiving, amplifying and transmitting signals to and from said base station, wherein said repeater is placed within said cell such that the distance d from said repeater to the closest point of the cell border line fulfils the following condition:

$$d < T_d \cdot c,$$

wherein T_d is a time delay introduced by said repeater when a signal is transmitted between said node and a mobile terminal within said cell via said repeater and c is the velocity for transmitting said signal.

In this way a cellular network is created wherein cells including a repeater have a maximal distance between the repeater and the closest point of the cell border to ensure that location calculation may be carried out with a reasonable accuracy.

According to another aspect of the present invention there is provided a cellular telecommunications network comprising a plurality of cells, and at least one cell including a repeater; said network being capable of distinguishing between a direct path and an indirect path of a signal being transmitted between a base station node of said network and a mobile terminal communicating via said network and wherein said indirect path is via said repeater; and wherein in said cell the distance d from said repeater to the closest point of the cell border fulfils the following condition:

$d < T_d \cdot c$,

wherein T_d is a time delay introduced by said repeater when a signal is transmitted between said node and a mobile terminal within said cell via said repeater and c is the velocity for transmits said signal.

Further aspects and advantages of the invention will be appreciated from the following description and accompanying drawings. Specific embodiments will now be described, by way of example only, with reference to the drawings, wherein:

Figure 1 is a schematic diagram of the general outline of a location service server in an UMTS environment according to the prior art in which the present invention can be implemented;

Figures 2a) to c) are schematic diagrams of UMTS cells indicating the distance between the base station Node B and the mobile terminal;

Figure 3 is a schematic diagram showing travelling times between the base station Node B and the mobile terminal according to one embodiment of the present invention;

Figures 4 and 5 show results of different placements of the repeaters as a function of the cell radius and for different values of the time delay T_d introduced by the repeater according to embodiments of the present invention;

Figure 6 is a flowchart diagram showing the steps of providing position information according to one embodiment of the present invention; and

Figures 7a) and b) are schematic diagrams showing communications between the user equipment base station and radio network controller in a user equipment based method and a network based method, respectively, to provide a location estimate calculation according to further embodiments of the present invention.

Location Services (LCS) are an important concept of modern mobile telecommunications systems like for example GSM and UMTS (universal mobile telecommunications system). LCS provide the capacity to determine the geographic location of the mobile user equipment (UE) by making use of radio signals. The location information may be requested by and reported to a client or client application associated with the UE or by a client within or attached to the core network. There are many different possible uses for the location information, it may be utilised internally by UMTS, by value-added (i.e. commercial) services, by the UE itself, by "third party" services or by an emergency service.

The positioning methods used in such cellular telecommunications systems include for example cell coverage based methods, RTT (round trip time) measurements, OTDOA (observed time different of arrival) and network assisted GPS (global positioning system) methods.

Figure 1 shows the general arrangement of a LCS server 1 in an UMTS architecture. The serving GPRS support node (SGSN) 6, the mobile switching centre (MSC) 8, the gateway mobile location centre (GMLC) 2 and the home location register (HLR) 4 are all elements of the core network.

Connected to the core network is the UMTS terrestrial radio access network (UTRAN) 10 which allows access from a user equipment (UE) such as a mobile station 20 to the core network. The SGSN 6 and MSC 8 are connected via communication links to the radio network controller (RNC) 12. The RNC 12 are dispersed geographically across areas served by the MSC 8. Each RNC 12 controls one or more base stations (Node B) 14 located remote from, and connected by further communication links to the RNC 12. A Node B 14 transmits radio signals to, and receives signals from a mobile station 20, which is in an area served by the serving Node B 14. This area is referred to as a "cell". A UMTS network is provided with a large number of such cells in a hierarchical cell structure. The network may also comprise repeaters 16. Repeaters are used for areas in which there is no adequate coverage by the base stations Node Bs 14 in order to provide reliable transmission of the radio signals, eg tunnels or near cell borders. The repeaters receive, amplify and transmit signals from and to the base station, and thus handle uplink and downlink traffic.

A UE Positioning function requests measurements, typically from the UE and one or more network nodes, sends the measurement results to the appropriate calculating function within UTRAN, receives the result from the calculating function within UTRAN, performs any needed co-ordinate transformations, and sends the results to the LCS entities in the core network or to application entities within UTRAN.

The GMLC 2 contains functionality required to support LCS. In one public land mobile network (PLMN), there may be more than one GMLC. The GMLC 2 is the first node an external LCS client 30 accesses in a PLMN. The GMLC 2 may request routing information from the HLR 4 or the SGSN 6. After performing registration authorisation, it sends positioning requests and receives final location estimates.

The serving GPRS support node 6 contains functionality responsible for UE subscription, authorisation and managing call-related and user-call related positioning requests of LCS. The LCS functions of SGSN 6 are related to charging and billing, LCS co-ordination, location request, authorisation and operation. The SGSN 6 of one LCS server 1 may further be connected to another LCS server 40 of a further PLMN. The RNCs 12 manage the UTRAN 10 resources like the Node Bs 14, the UEs 20 and the calculation functions. The serving RNC 12 receives authenticated requests for UE positioning information from the core network. The Node B 14 is a network element of UTRAN 10 that may provide measurement results for position estimation, makes measurements of radio signals and communicates these measurements to the RNC 12. The HLR 4 contains LCS subscription data and routing information.

There are two different classes of LCS clients or client applications: internal or external applications. International applications represent entities internal to the UMTS that make use of location information for the operation of the network. In this sense the serving RNC may for example use the

location information for position based handover. External applications, such as for example the LCS client 30 represent entities that make use of location information for operations externals to the mobile communications network, such as commercial or emergency services, as for example CAMEL (customised application for mobile network enhanced logic).

The measurements which are used to determine the position information may be used in two different ways: in network based or UE based modes. The two modes differ in where the actual location calculation is carried out. In the network based (or UE assisted) mode results of measurements, as for example the RTT measurement of Node B 14 and other measurements carried out by the UE20, are signalled to a network node such as a RNC 12, where a network element (the position calculation function) carries out the location calculation. In the UE based method, the UE 20 makes measurements, receives measurements and other information from the network and carries out the location calculation. For example, a RTT measurement made in the Node B 14 is signalled from the Node B14 to the UE. As the UE 20 needs additional information for the calculation, as for example the location of the base station Node B 14, it receives this information via signalling from the network, i.e. either directly from serving RNC 12 or from other network elements via the serving RNC 12. In the network based method, the RTT measurement is also made by the Node B14 and is then signalled to the RNC 12. Other information may in addition be

signalled to the RNC 12 and the RNC 12 then performs the location calculation.

A quantity frequently used for location calculations is the RTT (round trip time), i.e. the travelling time of a signal travelling from the Node B 14 to the UE 20 and back to the Node B 14. The RTT is defined as RTT = $T_{RX} - T_{TX}$, where T_{TX} is the time of transmission of the beginning of a downlink DPCH frame to a UE and T_{RX} is the time of reception of the beginning (the first significant path) of the corresponding uplink DPCCH/DPDCH frame from the UE.

With a single RTT measurement, the network can determine the position of a UE to lie on a circle with radius d of around the Node B, as is indicated in Figure 2a. Due to measurement errors the distance d between Node B and the UE can be determined only to a limited accuracy of $d \pm \Delta d$.

A RTT measurement can be expressed as

$$RTT = 2 \cdot T_1 + T_0 + X \qquad (1)$$

wherein T_1 is the time the signals needs to be transmitted between Node B and UE or between UE and Node B. T_0 is a characteristic time delay introduced by the UE, for example the time difference between the downlink DPDCH signal reaches the UE and the uplink signals is subsequently transmitted and X is the time delay that is introduced in NLOS (non line of sight) cases, i.e. the time delay that the first path takes to reach the UE from the Node B. T_0 may either be defined as a constant, wherein the uplink DPCCH/DPDCH frame transmission takes place approximately a time period

T_0 after the reception of the first detected path (in time) of the corresponding downlink DPCCH/DPDCH frame. Alternatively, a Rx-Tx time difference measurement performed by the UE itself may be used. The Rx-Tx time difference is defined as the difference in time between the UE uplink DPCCH/DPDCH frame transmission and the first detected path (in time) of the downlink DPCH frame from the measured radio link. Two different types are defined. For type 1, the reference Rx path shall be the first detected path (in time) amongst the paths (from the measured radio link) used in the demodulation process. For type 2, the reference Rx path shall be the first detected path (in time) amongst all paths (from the measured radio link) detected by the UE. The reference path used for the measurement may therefore be different for type 1 and type 2. The reference point for the UE Rx-Tx time difference is usually the antenna connector of the UE. The travelling times between Node B and UE are schematically outlined in Figure 3.

Using the relationship between distance d, travelling time T and the velocity of light c ($c = \frac{d}{T}$), RTT can be expressed as a function of the distance d_1 between the Node B and the UE according to equation (1) as

$$RTT = 2 \cdot \frac{d_1}{c} + T_0 + X \qquad (2)$$

However, when the signal that is used for the time measurement "passes" through a repeater, the signal is transmitted via the path Node B $\rightarrow$ repeater $\rightarrow$ UE $\rightarrow$ repeater $\rightarrow$ Node B. An example for such a case is

schematically shown in Figure 2b. The distance from Node B to the UE via the repeater is then given by $d_2 + d_3$ rather than by d_1, whereby d_2 is the distance between Node B and the repeater and d_3 is the distance between the repeater and the UE. In addition, a further time delay T_d is introduced by the repeater itself, i.e. by the internal filtering of the repeater. T_d may either be known or measured by the repeater. In an UMTS network according to an embodiment of the present invention, the technology used in the RF repeater to enable the filtering of the carrier introduces a typical time delay of about 5 to 6 μs. For comparison, the travelling time of a signal between the base station and the repeater for this embodiment is typically in the range of 4 to 8 μs and between the repeater and the mobile station in the range of 1 to 4 μs.

Due to the delay introduced by the repeater and the different path Node B → repeater → UE → repeater → Node B (rather than the direct path Node B → UE → Node B) the measured RTT' is considerably higher than the RTT for the direct path would be. So, the distance R' that the network calculates accordingly is also considerably higher than the correct distance would be. In these cases where a repeater is present in the cell, the accuracy is substantially degraded due to the fact that the delay introduced by the repeater itself corresponds typically to a minimum of 1.3km. Thus the error introduced by a repeater will be $\Delta d \geq 1.3$ km.

The correct expression for such a RTT measurement where a repeater is present in the cell would therefore be

$$RTT = 2 \cdot (T_2 + T_d + T_3) + T_0 + X \qquad (3)$$

$$= 2 \cdot \left(\frac{d_2}{c} + T_d + \frac{d_3}{c} \right) + T_0 + X,$$

whereby T_2 and T_3 is the time the signal travels from Node B to the repeater and from the repeater to the UE, respectively and X is again the time delay caused by multipath situations.

The magnitude of the delays introduced by the internal delay time of the repeater T_d can now be used to identify those cases where the signal travels via the repeater. For certain deployment scenarios of the system, it can be distinguished if a measured RTT corresponds to a RTT for a direct path or a RTT measurement where the signal travelled via the repeater. For example, if in a cell a RTT of typically around 5 µs is expected and a RTT of 8 µs is measured, it is likely that the signal travelled via the repeater.

In order to identify the cases where a signal travelled via the repeater, the measured RTT values are compared to the "maximal" expected travel time RTT_{max} a signal may need for the direct path. The "maximal" time RTT_{max} is given by

$$RTT_{max} = 2 \cdot T_{max} + T_0 + X = 2 \cdot \frac{d_{max}}{c} \cdot T_0 + X \qquad (4)$$

whereby d_{max} is the distance from the Node B to the cell border as is schematically shown in Fig. 2c and T_{max} is the according time the signal travels from Node B to the cell border line.

By comparing equations (3) and (4), the following relationship can be derived in order to distinguish a signal travelling directly between node B and UE and a signal travelling via the repeater:

If the measured time RTT is greater than the travelling time expected from equation (4), then it can be assumed that the signal travelled from Node B to the UE via the repeater. In this case d_3 (i.e. the distance between the repeater and the UE) can be estimated using equation (3). The time delay T_d introduced by the repeater and the distance d_2 between the Node B and the repeater are known and are provided for the position estimate. Also, T_0 is either known or can be measured by the UE. X could be determined using techniques known in the art. Thus, instead of using the Node B as a reference point for the location estimate the repeater can be used. The result may possibly even be better due to the fact that a UE is very likely to be close to the repeater. Thus, by possibly having line of sight or at least a very limited delay of the first multipath from the repeater, this approach can yield better results compared to the direct path between the Node B and the UE. Alternatively, both the Node B's and the repeater's site may be used as reference points at the same time.

If, on the other hand, the measured time RTT is smaller than the travelling time RTT_{max} expected from equation (4), then it can be assumed that the signal travelled directly between Node B and the UE. In this case the position estimate is based on the Node B as a reference point and d_1 can be estimated using equation (2).

It is noted that the maximal RTT value RTT_{max} can only be known with a limited accuracy. Typically fluctuations of about 10% are expected. Nonetheless, the relatively great delay introduced by the repeater helps in many scenarios to determined the path of the signal for a RTT measurement. It will be discussed below which conditions of the deployment scenario have to be fulfilled in order to be able to identify indirect signal paths via a repeater.

The block diagram of Figure 6 gives an outline of a position calculation process in the presence of a repeater in a cell. In step 301 a request of a position estimate is given by an LCS client. A RTT measurement is requested in step 302. It is determined in step 303 whether a repeater is present in the according cell. If no repeater is present, then the normal procedure is used to calculate the position of the UE in the PCF (positioning calculation function) in step 304. However, if a repeater is present, then the maximal RTT value RTT_{max}, the time delay T_d of the repeater and the distance d_2 of the Node B to the repeater are provided to the PCF. In step 306 the measured RTT is compared to the maximal RTT_{max} as provided in step 305. If the measured RTT is smaller than the maximal RTT value RTT_{max}, then the existing procedure is used to calculate the UE position in step 304. Otherwise it is now assumed that the signal travelled on the indirect path via the repeater (step 308). In this case it is now determined whether the repeater site shall be used as a reference point for the location estimate (step 309). Whether the Node B site, the repeater site or both are used in the position calculation

depends on the availability of the measurements and on the implementation in the PCF. In step 310 the position is subsequently determined in the PCF with the information provided in step 305.

In the following two different embodiments will now be described with reference to Figure 7. First a UE based method of positioning calculation will be described. In step 401 the Radio Network Controller RNC receives a LCS request. The RNC then determines if the cell is one which includes a repeater in step 402 and requests a RTT measurement in step 403. Node B then performs the measurements (step 404) and reports the measured RTT result to the UE in step 405. The UE may perform other measurements, like for example a Rx-Tx measurement, in step 406. In step 407, the RNC provides other information like for example the time delay T_d of the repeater, the maximal RTT value RTT_{max} and the distance d_2 between the Node B and the repeater and subsequently signals the information to the UE, so that the UE can then calculate its position in step 408. Information may also be signalled from any other network node via the serving RNC to the UE, either alternatively or in addition to the information provided by the RNC. The UE then reports the position to the RNC in step 409.

With reference to Figure 7b now a network based (or UE assisted) method of positioning calculation will be described. Steps 501 to 504 are equivalent to steps 401 to 404 of Figure 7a. In step 505 the Node B reports the RTT measurement to the RNC. The UE may perform other measurements like the Rx-Tx measurement in step 506 and reports the results via the Node B

to the RNC in step 510. Other information like for example the time delay T_d, RTT_{max} or d_2 may either be present in the RNC or may be signalled from other network nodes to the RNC. The location of the UE is then calculated in the RNC in step 511. The position estimate may for example be based on the RTT measurement of the Node B, the other measurements as provided by the UE and the known values of the repeater time delay T_d, the maximal RTT value RTT_{max} and the distance d_2.

It can be seen from the flowcharts of Figures 7a and 7b that the additional signalling required for supporting the improved RTT measurement in the presence of repeaters in the cell is very limited and does not add substantial additional complexity.

Equations (3) and (4) can now be used to derive conditions for the deployment of repeaters when designing a network in order to ensure that it is possible to identify whether the signal travelled on an indirect path via a repeater.

As stated above, in scenarios where the measured time RTT for a signal travelled via a repeater is greater than the maximal RTT value RTT_{max} expected the indirect path can be identified. Thus, by combining equations (3) and (4), i.e. comparing the maximal RTT value RTT_{max} for a direct signal path to the RTT measurement for an indirect signal path via the repeater, the following relationships can be derived:

$$d_{max} < d_2 + d_3 + T_d \cdot c \qquad (5)$$

For equation (5) and the following equations we used the assumption that the time delay X caused by multipath situations cancels. This is, especially for cases where the UE is situated close to the repeater, a reasonable approximation. Alternatively, estimates for the multipath time delay according to the art may be used. From e.g. (5) and by defining a distance d_4 between the cell border and the repeater ($d_4 = d_{max} - d_2$) and approximately $d_3 = 0$ (assuming that the mobile station is close to the repeater) it follows:

$$d_4 < T_d \cdot c \tag{6}$$

Thus a maximal distance d_4 between the cell border and the repeater can be determined in dependence of the time delay T_d introduced by the repeater. A cell design of a cellular network in which repeaters are placed at a distance d_4 that satisfied equation (6) will allow to distinguish a direct and indirect signal path.

For example, if a repeater introduces a delay of 6 μs, the distance between the cell border and the repeater has to be at most 1800m in order to be able to distinguish between a direct or indirect path.

Another useful quantity to characterise a deployment scenario of a cell is the ratio A of d_2 (the distance between Node B and the repeater) and d_{max} (the distance between Node B and the cell border line). Using $A = d_2/d_{max.}$, equation (5) can be rewritten as:

$$d_{max} < T_d \cdot c / \left(1 - A - \frac{d_3}{d_{max}}\right) \tag{7}$$

Equation (7) can thus be used to derive a maximal radius R of a cell in dependence of the time delay T_d and the ratio A, for which RTT measurements in cells including a repeater can be identified as resulting from direct or indirect signal paths. B approximating $d_3 = 0$, it follows:

$$R < T_d \cdot c / (1 - A) \tag{8}$$

The maximal cell radius R as defined in equation (8) is thus derived from the case that the user station UE is very close to the repeater.

For example if the repeaters in the cells of a cellular network are all placed at a minimal distance from Node B of at least half way between the Node B and the cell border (i.e. $A \geq 0.5$), and the repeater time delay T_d is 6µs, then the resulting maximal cell radius R is 3600m. If we allow for a 10% fluctuation of the area coverage by the Node B, it is safe to say that for a maximal cell radius R of $R < 0.9 \cdot 3600\text{m} = 3240\text{m}$ the path of the signal can be identified as direct or indirect.

With reference to Figures 4 and 5 results regarding different combinations of cell radius R and repeater delay time T_d are presented which allow to identify the signal path. Figure 4 indicates the minimal distance a repeater may have to the base station Node B i.e. the ratio A of the distance d_2 between Node B and the repeater and the cell radius d_{max}, as a function of the cell radius for a repeater time delay T_d of 6µs. If we assume for example a minimal ratio A of 0.5. i.e. all repeaters have a distance from the Node B of at least 50% of the outer radius of the cell, then for all cells with a maximal radius of 3000m the path can be identified.

Figure 5 indicates the minimal distance between a repeater and Node B (i.e. the ratio A,) as a function of the cell radius R for four different typical values of the repeater time delay T_d between 4 µs and 7µs. The ratio A is shown for certain cell radii between 2000m and 20km and in dependence of the repeater delay time T_d. If a cell has for example a cell radius of 3000m and a repeater delay time T_d of 5µs, then the repeater needs to be at a distance of at least 50% of the cell radius ($A \geq 0.5$). For a cell of 15km and a repeater time delay T_d of 6µs, the repeater needs to be placed at least at a distance of about 90% of the cell radius ($A \geq 0.9$). i.e. at least 13.5km away from Node B.

It follows from Figures 4 and 5 that for large cell sizes the repeaters have to be placed close to the cell border in order to allow the distinction between direct and indirect signal paths. Of course, the main reason for the deployment of repeaters is to ensure a sufficient coverage throughout the cell. However, if the site of the repeater has to be determined and more than one place can be selected for a particular repeater, it is advantageous to choose the place closest to the cell border in order to be able to identify the signal path.

From Figure 5 it can be seen that the higher the internal delay of the repeater is, the less strict the criteria are for the repeater deployment (i.e. the minimal distance they may have from the base station) and for the cell size (the maximum size a cell may have).

Thus it is shown that satisfactory results for distinguishing between direct and indirect signals paths can be achieved in cells where a repeater is

present for typical time delays T_d introduced by the repeater of about 6 μs in the following scenarios:

i) in urban areas where a large percentage of the cells will have a coverage less than 2 to 3 km;

ii) in rural areas where repeaters are expected to be near the cell border for an extension of the coverage.

Whilst in the above described embodiments a RTT measurement is described, it is appreciated that other time measurements suitable to determine location information may be used instead or in addition to the RTT measurement according to the present invention. For example, a Rx-Tx measurement may be performed by the UE in order to determine the time delay T_0.

Whilst in the above described embodiments a repeater is described, it is appreciated that according to the present invention, path information with respect to any other intermediate node between a base station node and a mobile terminal may be determined.

Whilst in the above described embodiments a cellular network according to the UMTS standard is described, it is appreciated that the present invention may be implemented in other cellular networks like for example a GSM network.

It is to be understood that the embodiments described above are preferred embodiments only. Namely, various features may be omitted,

modified or substituted by equivalents without departing from the scope of the present invention, which is defined in the accompanying claims.

CLAIMS

1. A method of distinguishing, based on timing information, between a first path and a second path of a signal being transmitted between a node of a cellular network and a mobile terminal in a cell of said network, wherein

said first path is a direct path between said node and said mobile terminal; and

said second path is an indirect path between said node and said mobile terminal via an intermediate node of said cellular network.

2. A method according to claim 1, wherein said timing information comprises:

a time measurement t related to the transmission time of a signal between said mobile terminal and said node: and

a reference value for a time delay T_d introduced by said intermediate node.

3. A method according to claim 1 or 2, wherein said timing information further comprises

a reference value t_{ref} for said time t related to the transmission time of a signal between a mobile terminal situated on the border of said cell and said node.

4. A method according to any of claims 1 to 3, wherein all said timing information is based on signals transmitted within said cell.

5. A method according to any of claims 1 to 4, wherein only one time measurement related to the transmission time of a signal between said mobile terminal and said node is used to determine the path information.

6. A method according to any of claims 1 to 5, wherein said intermediate node is a repeater.

7. A method of determining position information of a mobile terminal in a cell of a cellular telecommunications network, comprising the steps of:

determining whether an intermediate node is present in said cell;

determining path information of a signal transmitted between a base station node and said mobile terminal if said intermediate node is present in said cell; and

calculating said position information.

8. A method according to claim 7, wherein said path information comprises the information whether said signal is transmitted via said intermediate node.

9. A method according to claim 7 or 8, wherein a time measurement t related to the signalling time between said base station node and said mobile terminal is compared to a reference value t_{ref} for determining said path information and wherein said reference value t_{ref} is related to a measurement of time t for a mobile station located on the border of said cell.

10. A method according to claim 9, wherein said time t is a round-trip-time.

11. A method according to claim 10, wherein the distance d between said base station node and said mobile terminal is calculated according to

$$d = (t - 2T_d - T_0) \cdot c/2, \text{ or}$$

$$d = (t - 2T_d - T_0 - X) \cdot c/2$$

whereby t is the measured round-trip-time between said base station node and said mobile terminal;

T_d is a reference value for a time delay introduced by said intermediate node for receiving and transmitting said signal;

T_0 is a reference value for a time delay introduced by said mobile terminal;

X is a multipath term;

and c is the transmission velocity of said signal.

12. A method according to claim 10 or 11, wherein the distance d_3 between said intermediate node and said mobile terminal is calculated according to

$$d_3 = (t - 2T_d - T_0) \cdot c/2 - d_2, \text{ or}$$

$$d = (t - 2T_d - T_0 - X) \cdot c/2$$

whereby t is the measured round-trip-time between said base station node and said mobile terminal;

T_d is a reference value for a time delay introduced by said intermediate node for receiving and transmitting said signal;

T_0 is a reference value for a time delay introduced by said mobile terminal;

X is a multipath term;

and c is the transmission velocity of said signal.

and d_2 is the distance between said base station node and said intermediate node.

13. A method according to any of claims 7 to 12, wherein a reference value T_d for a time delay introduced by said intermediate node is used for determining said path information.

14. A method according to any of claims 7 to 13, wherein said path information is derived from a single time measurement.

15. A method according to any of claims 7 to 14, wherein said intermediate node is used as a reference point to calculate said position information.

16. A method according to any of claims 7 to 15, wherein said base station node is used as a reference point to calculate said position information.

17. A method according to any of claims 7 to 16, wherein said method is implemented in a cellular network according to the UMTS standard.

18. A computer program in a cellular telecommunications network capable of determining, based on timing information, whether a signal was transmitted between a mobile terminal and a node within a cell of said cellular network via an intermediate node, and wherein said timing information comprises:

a time measurement t related to the transmission time of a signal between said mobile terminal and said node; and

a reference value for a time delay T_d introduced by said intermediate node.

19. A computer program according to claim 18, wherein said timing information further comprises:

a reference value t_{ref} for said time t related to the transmission time of a signal between a mobile terminal situated on the border of said cell and said node.

20. A computer program according to claim 18 or 19, wherein time t is a round-trip-time.

21. A computer program according to claim 18, 19 or 20, wherein said intermediate node is a repeater.

22. A computer program according to any of claims 18 to 21, further capable of determining position information related to the position of said mobile terminal using said timing information.

23. A mobile terminal for use in a cellular network adapted to implement a computer program according to any of claims 18 to 22.

24. A node of a cellular network, adapted to implement a computer program according to any of claims 18 to 22.

25. A positioning calculation function in a cellular network, adapted to implement a computer program according to any of claims 18 to 22.

26. A positioning calculation function according to claim 25, adapted to receive said time measurements and said reference values via signalling within said cellular network.

27. A method of designing a cellular telecommunications network, said network comprising a plurality of cells, at least one cell including a base station and a repeater for receiving, amplifying and transmitting signals to and from said base station,

wherein said repeater is placed within said cell such that the distance d from said repeater to the closest point of the cell border line fulfils the following condition:

$d < T_d \cdot c$,

wherein T_d is a time delay introduced by said repeater when a signal is transmitted between said node and a mobile terminal within said cell via said repeater and c is the velocity for transmitting said signal.

28. A method of designing a cellular telecommunications network, said network comprising a plurality of cells, at least one cell including a base station and a repeater for receiving, amplifying and transmitting signals to and from said base station,

wherein said repeater is placed within said cell such that the cell radius R fulfils the condition:

$R < T_d \cdot c / (1 - A)$,

wherein T_d is a time delay introduced by said repeater when a signal is transmitted between said node and a mobile terminal within said cell via said repeater and c is the velocity for transmitting said signal.

and A is the ratio of the distance d_2 and the cell radius R, whereby d_2 is the distance between said base station node and said repeater.

29. A cellular telecommunications network comprising a plurality of cells, and at least one cell including a repeater;

said network being capable of distinguishing between a direct path and an indirect path of a signal being transmitted between a base station node of said network and a mobile terminal communicating via said network and wherein said indirect path is via said repeater;

and wherein in said cell the distance d from said repeater to the closest point of the cell border fulfils the following condition:

$d < T_d \cdot c$,

wherein T_d is a time delay introduced by said repeater when a signal is transmitted between said node and a mobile terminal within said cell via said repeater and c is the velocity for transmits said signal.

Application No: GB 0119354.9
Claims searched: 1-27

Examiner: Robert Shorthouse
Date of search: 5 June 2002

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): H4L (LRPLS,) H4D

Int Cl (Ed.7): H04Q 7/38, G01S

Other: Online: WPI, EPODOC, JAPIO, INSPEC

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2338374 A	(MOTOROLA) See abstract	-
A	WO 98/05172 A1	(NOKIA) See abstract	-
A	US 6121927	(KALLOJARVI) See abstract	-

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